Research Investigation 00-01

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# Type A Water Reducers in MoDOT's PCCP Mixes

Research Development and Technology

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**Project Description**

In MoDOT's quest for improving the condition of the state transportation system, it is necessary to explore any opportunities to improve the performance of our PCC pavements at a lower cost. Recently, Research, Development, and Technology, pursued investigating the addition of a Type A water reducer while reducing cement content in PCCP mixes. It was proposed that adding a water reducer will lower the water/cement ratio and promote complete hydration of cement particles resulting in an improved hardened concrete product, despite a ¼-sack reduction (per cubic yard) in cement content.

This investigation was a two-part study that consisted of both laboratory and field results of PCCP mixes containing a Type A water reducer with cement reductions. The laboratory study consisted of ten different mix designs containing various combinations of Type A water reducer dosages and cement content, including control mixes with no water reducer. The field study consisted of testing a PCCP mix from a district paving project containing a Type A water reducer and a ¼-sack cement reduction in its design. A standard field mix containing no water reducer and no cement reductions was also tested for comparison purposes. In both the laboratory and field studies, concrete specimens were fabricated from each mix and were tested for the following concrete characteristics:

- 7 and 28 day compressive strength (AASHTO T22)
- 28-day flexural strength (AASHTO T177 or AASHTO T97)
- freeze/thaw durability (AASHTO T161)
- air void analysis (ASTM C457)
- rapid chloride permeability (AASHTO T277).

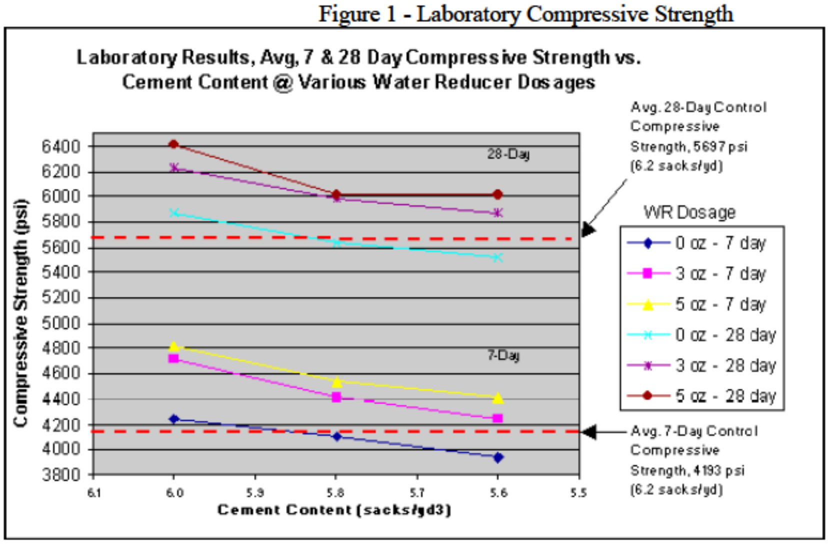
**Compressive Strength (AASHTO T22)**

*Laboratory Results*

Figure 1 illustrates the effect on compressive strengths when varying the cement content and the dosage of water reducer for the mixes developed in the laboratory. (Note: dashed horizontal lines denote the average 7 and 28-day compressive strengths of the control mix.)

The general trend for the laboratory results follow that for a given cement content, mixes containing 5 oz./sack of water reducer had greater compressive strengths than the mixes with lower water reducer dosages. Another observation of the water reducer is that it provided the concrete with greater compressive strengths compared to the control mix, even at the lowest cement content.

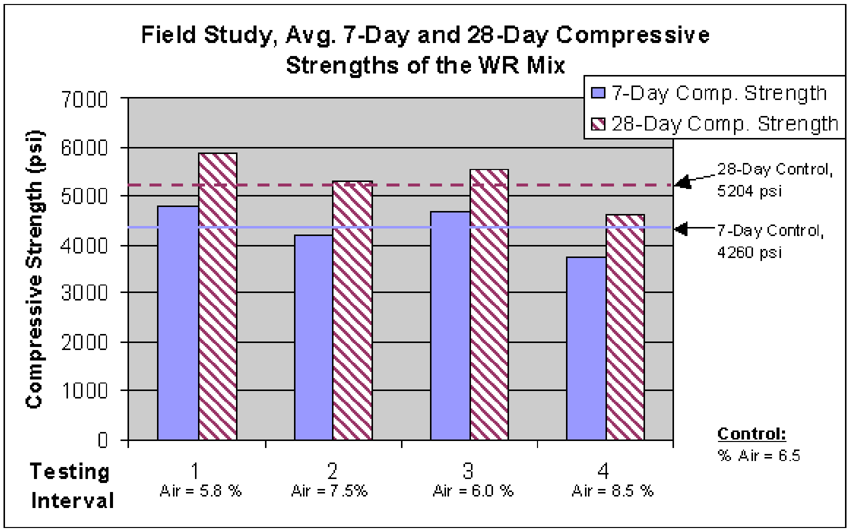
Figure 1 - Laboratory Compressive Strength




*Field Results*

Compressive strength data were also collected from 7 and 28-day concrete cylinders taken from both the control mix and the water reducer mix that were produced in the field. Figure 2 illustrates the average 7 and 28-day compressive strength of the field water reducer test mixes and compares them to the control. The average 7 and 28-day compressive strengths of the field control mix are denoted in the figure by the lower and upper solid/dashed lines, respectively.

Figure 2 - Average 7 and 28 Day Compressive Strengths




As Figure 2 illustrates, the water reducer appears to increase compressive strength despite the ¼-sack cement reduction in the mix. The only exception to this is when the air content of the WR mix is relatively higher compared to the control.

**Flexural Strength (AASHTO T-177 and AASHTO T-97)**
*Laboratory and Field Results*
The flexural strength results for the laboratory study were too inconclusive. The laboratory flexural tests were conducted according to AASHTO T-177, which varied considerably between companion test specimens.

Field flexural strengths were conducted according to AASHTO T-97, which provided a more thorough flexural test and more comparable results. The flexural strength of the WR mix followed the same general trend as the compressive strength. The flexural strength of the water reducer mix was higher than the control, except when the air content of the WR mix exceeded the control. Table 1 lists the 7 and 28 flexural strengths of the WR mix and the control mix from the field project.

Table 1- Field Study, 7 and 28-Day Flexural Strength

| Mix Interval | Avg. % Air | Avg. 7-Day Flexural Strength, psi | Avg. 28-Day Flexural Strength, psi |
|---|---|---|---|
| WR 1 | 5.8 | 681 | 694 |
| WR 2 | 7.5 | 627 | 663 |
| WR 3 | 6.0 | 629 | 680 |
| WR 4 | 8.5 | 538 | 600 |
| Avg. Control | 6.5 | 631 | 668 |

**Freeze/Thaw Durability (AASHTO T161)**
*Laboratory Results*
All PCC mixes tested in the laboratory had an average freeze/thaw (F/T) durability factor in the range of 95 -97. There was no indication of superior or inferior freeze/thaw performance by the addition of water reducer in any mix design. Even the PCCP mixes that had the lowest cement content and contained no water reducer performed well. The aggregate used in the PCCP mixes for this laboratory study had a good F/T performance history, thus any substandard results would have been due to the effects of the water reducer and/or reductions of cement to the PCCP mix.

*Field results*
Although the water reducer mix had a lower average F/T durability factor compared to the control mix, both mixes obtained an average F/T durability factor less than 60, which is substandard. The F/T testing results indicate that the coarse aggregate used in this study was questionable on its resistance to freezing and thawing cycles. Due to the likely substandard aggregate, no valid comparisons could be made between the WR mix and the control mix.

**Air Void Analysis (ASTM C457)**
The PCCP mixes specimens from both laboratory and field studies had an adequate air void structure for good freeze/thaw durability. The bubble spacing factors, specific surfaces, and void size distributions were within the proper ranges. Despite this, good freeze/thaw performance from the field did not occur. This further indicates that the aggregate quality of the materials in the field may have not been satisfactory.

**Rapid Chloride Permeability (AASHTO T 277)**
PCCP mixes containing water reducer and decreased cement content closely compare to that of the control mixes from both laboratory and field testing. The water reducer in combination with a reduced cement content appeared to decrease the average permeability, but all mixes were considered to be within the same moderate permeability range.

**Key Findings**
The main findings of this investigation can be summarized as follows:

- PCCP mixes containing a Type A water reducer and at least a ¼-sack reduction in cement showed increases in compressive and flexural strength compared to a conventional mix. Both mixes were produced at approximately the same water/cement ratios.

- The laboratory freeze/thaw results indicated no additional benefit or detriment to freeze/thaw resistance for the mixes containing water reducer and lower cement content. All laboratory mix designs achieved above a 95 freeze/thaw durability factor.

- The field freeze/thaw results indicated poor freeze/thaw performance (< 60 durability factor) by both the control and water reducer mixes. The poor durability is probably due to the quality of the aggregate, but further testing is needed to verify this. The control mix had approximately 12% higher durability compared to the water reducer mix. This may be partly due to the relatively lower air contents in two of the water reducer mix samples compared to the control mix.

- The water reducer does not appear to alter the air void structure in the concrete and demonstrated to produce the proper air bubble spacing factor, specific surface, and size distribution for good freeze/thaw performance.

- The PCCP mix containing the water reducer with a ¼-sack reduction in cement cost less than a standard PCCP mix. The proposed savings for the field demonstration project was approximately $0.28 per cubic yard.

**Recommendations**

Based upon laboratory and field testing results and observations, Research, Development, and Technology recommends that Type A water reducers can be used to obtain equivalent or better concrete characteristics at lower costs compared to conventional PCCP mixes. Further testing of field PCCP mixes containing different brands of Type A water reducers, ¼-sack cement reductions, and acceptable aggregate materials is needed in order to validate improved or equivalent freeze/thaw resistance of these mixes compared to conventional field PCCP mixes.

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